3. VITAL SIGNS

Vital Signs are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. (http://science.nature.nps.gov/im/monitor/). Due to the large number of potential vital signs that can be used to monitor the state of an ecosystem, it was imperative for the GRYN to identify and prioritize potential indicators and then select a subset that best represents the parks' ecosystems. This chapter describes the process used by the GRYN to select and prioritize potential indicators as vital signs for the network.

IDENTIFYING POTENTIAL VITAL SIGNS

In addition to the conceptual modeling process (described in Chapter 2), the GRYN used a Delphi survey and workshops at the parks to identify potential vital signs and the attributes that make these vital signs high-quality indicators of ecosystem health.

Delphi Survey

In 2001 the GRYN, in cooperation with the University of Idaho—College of Natural Resources, conducted an Internet-based Delphi survey to aid in the identification and prioritization of ecosystem components, conditions and processes. Over 100 scientists and resource managers familiar with the GRYN parks participated in the survey.

The Delphi process consisted of three rounds of questioning, starting with general resource issues and culminating at specific monitoring needs. Phases I and II of the Delphi process were used to solicit input, while the third phase of the Delphi process solicited rankings from the experts on the importance of ecosystem indicators derived from the resource components, conditions and processes identified in the first and second phases. This process resulted in a list of 188 possible indicators that are ranked within subject areas. Please see Appendix IV for the list of indicators resulting from Delphi III.

The Delphi survey approach to nominating potential indicators had advantages, including:

- the opportunity to obtain ideas from a large audience
- convenience—participants can respond when and where they choose
- cost effectiveness—no travel time or costs involved.

However, the Delphi process used by the GRYN had disadvantages, as well, including:

- that participants can nominate any vital sign they choose, with no peer-reviewed evaluation as to merit or relevance of ideas
- since the survey is voluntary, results will be skewed to the interests and expertise of those who chose to reply
- the results are not repeatable and therefore less defensible.

Park Workshops and Meetings

In conjunction with the Delphi survey process and conceptual modeling efforts, the GRYN held workshops with park staff at Grand Teton and Yellowstone. The purpose of these workshops and meetings was to provide updates and receive input on the following:

- the two methods used to identify candidate vital signs: conceptual modeling and the Delphi on-line survey
- the proposed criteria and process to rank and select vital signs from the list of candidate vital signs.

Conceptual modeling efforts were reviewed with respect to validity of spatial and temporal scale and unit of ecosystem organization. At Yellowstone, the results of the final Delphi questionnaire were reviewed and critiqued. Because some participants were uncomfortable with the Delphi scoring process, and a number of newly nominated vital signs had yet to be scored, a decision was made to prioritize candidate vital signs through a highly structured workshop setting by using a set of selection criteria based on scientific literature and I&M guidance.

SELECTING VITAL SIGNS

Vital Signs Monitoring Workshop

After completing the conceptual modeling and Delphi survey processes, the GRYN hosted a vital signs monitoring workshop to gain expert input into the selection of vital signs. The GRYN invited 56 subject-area experts to convene in Bozeman, Montana, for a three-day workshop with the goal of prioritizing a long list of potential vital signs and, through a scoring process, highlighting valuable indicators for monitoring long-term ecosystem health in the parks.

Prior to the workshop, GRYN staff cross-walked potential vital signs nominated through the Delphi survey and conceptual modeling exercises. The resulting list was then given to workshop participants to prioritize using a set of selection criteria. The selection criteria consisted of 13 yes/no questions based on I&M guidance and literature that identified the qualities of a good indicator. The five categories of selection criteria (and weighting) were as follows:

(1) Ecological relevance (25%)—Does the vital sign help us understand long-term ecosystem health?

(2) Response variability (25%)—Is the vital sign tightly coupled to, and preferably anticipatory of, the change(s) occurring?

(3) Managerial relevance (20%)—Does the vital sign address current or foreseeable management issues?

(4) Feasibility of implementation (15%)—Can the vital sign be measured at a reasonable cost, and can sampling protocols be designed to eliminate personnel-induced variability?

(5) Interpretation and utility (15%)—Can the vital sign differentiate between natural and anthropogenic change and identify the cause of ecosystem change?

A scoring system, essentially as follows, was then devised to quantify the group's expert knowledge regarding the ability of a potential indicator to address the 13 desirable vital signs criteria. For a more complete description of the scoring method, see Appendix V.

$$\textit{vital sign ranking} = \sum_{n=1}^{5} \left\{\frac{\textit{(\# "yes" answers per category)}}{\textit{(\# questions per category)}}\right\} \times \textit{(category weight)}$$

The selection criteria are presented in Table 3.1. The binary nature of these questions was meant to attach a quantitative value to the qualitative process of choosing vital signs. After the breakout ses-

TABLE 3.1 Vital sign selection criteria.

Category	Criteria (yes or no?)
Ecological Relevance	1. The candidate vital sign has high ecological importance with a demonstrated linkage between the vital sign and the ecological structure or function that it is supposed to represent, based on a conceptual model and/or supporting ecological literature. 2. The candidate vital sign provides relevant information that is applicable to multiple scales of ecological organization.
Response Variability	3. The candidate vital sign responds to ecosystem stressors in a predictable manner with known statistical power. 4. The candidate vital sign is anticipatory and is sensitive enough to stressors to provide an early warning of change. 5. The candidate vital sign has low natural variability and has high signal-to-noise ratio (e.g. low error) and/or supporting ecological literature.
Management Relevance	6. The candidate vital sign is stated in specific park management goals, GPRA goals or business plan standards. 7. There is a demonstrated, direct application of candidate vital sign measurement data to current key management decisions or for evaluating past management decisions.
Feasibility of Implementation	8. The candidate vital sign's cost of measurement is not prohibitive. 9. Impacts of measuring the candidate vital sign meet NPS standards. 10. The candidate vital sign is relatively easy to measure and has measurable results that are repeatable with different personnel.
Interpretation and Utility	11. The response of the candidate vital sign can be distinguished between natural variation and anthropogenic impact-induced variation. 12. The candidate vital sign is helpful in identifying the causal mechanism of an ecological response. 13. Historic databases and baseline conditions for the candidate vital sign are already known.

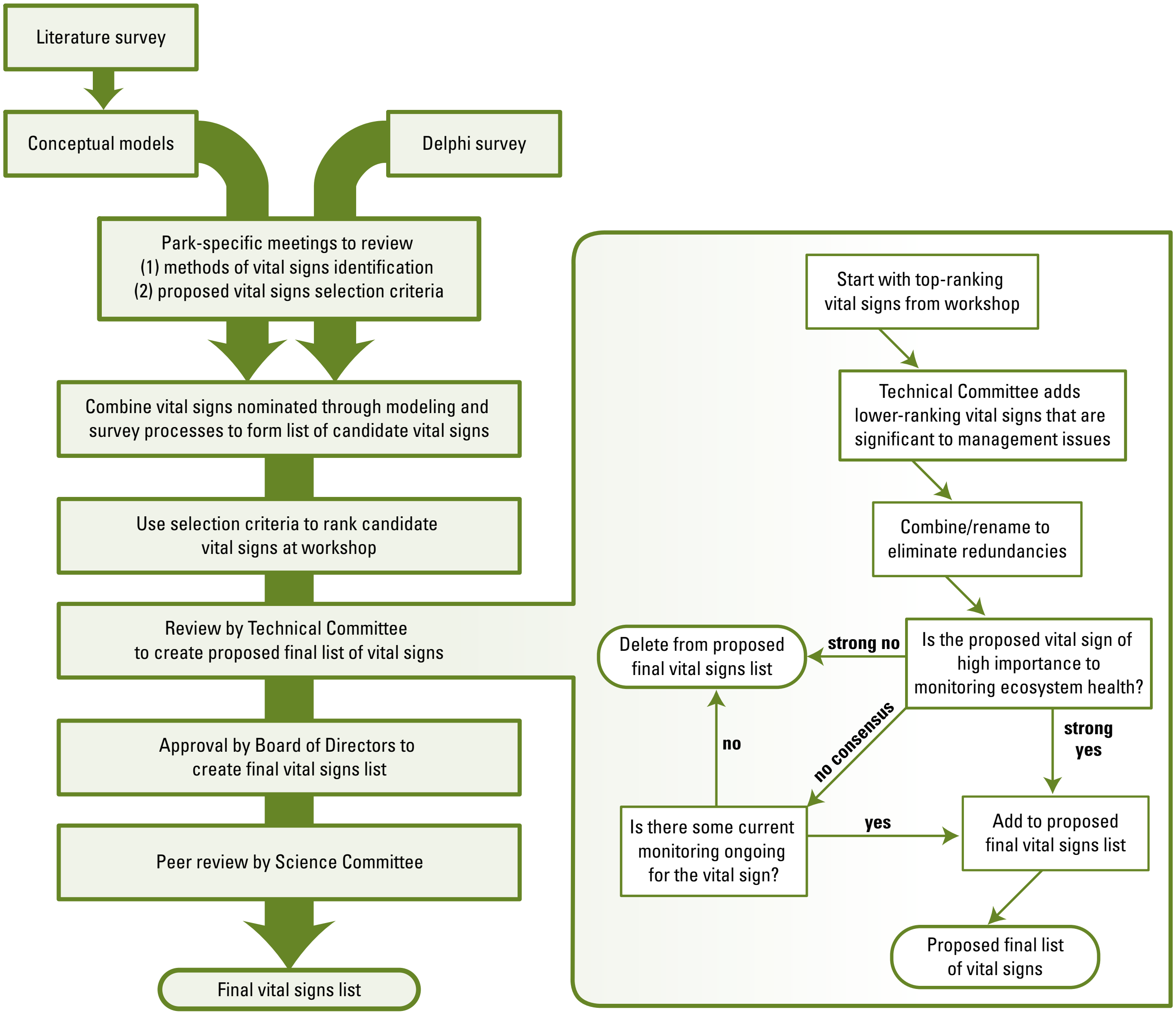

FIGURE 3.1 Vital signs selection process.

sions were complete, GRYN staff entered the responses into a database and presented the ranked list of potential indicators to workshop participants the following day for review and comments. Please consult Figure 3.1 for a diagram of the vital sign selection process. A report detailing the results of the workshop, along with the ranked list of vital signs and a list of participants, can be found in Appendix V.

The vital signs workshop provided an excellent venue for incorporating expert opinion and knowledge into the GRYN planning and decision process. This was the only workshop, except the park meetings, held to identify and prioritize candidate vital signs. Participants were enthusiastic and answered all the criteria for every vital sign and the resulting scores were instrumental in building the final vital signs selected by the GRYN.

TECHNICAL COMMITTEE VITAL SIGNS SELECTION MEETING

With a ranked list of potential indicators in hand, GRYN staff met with Technical Committee (TC) members to develop the final list of vital signs to be monitored in the network. GRYN staff believed that the park-specific management knowledge the TC members brought to the network was an extremely important component in the development of a list of vital signs. This involvement was also important due to concerns expressed by workshop participants that they could not address the management relevance of many potential vital signs.

To begin the process, the TC was provided with the ranked list of potential vital signs from the workshop. TC members were then told

TABLE 3.2 List of vital signs for the Greater Yellowstone Network of parks.

Level 1	Level 2	Vital Sign	BICA	GRTE	YELL
Air and Climate	Air Quality	Atmospheric deposition	✧	✧	•
		Oversnow emissions	–	✧	•
		Visibility	–	✧	•
	Weather	**Climate**	✚	✚	✚
Geology and Soils	Geomorphology	Glaciers	–	✧	–
		Stream sediment transport	✧	✧	✧
	Subsurface Geologic Processes	Geothermal features	–	✧	•
		Geothermal water chemistry	–	✧	•
		Seismic activity	✧	•	•
	Soil Quality	**Soil structure and stability**	✚	✧	✧
		Soil biota	✧	✧	✧
Water	Hydrology	Ground water quantity	✧	✧	✧
		Arid seeps and springs	✚	–	–
		Reservoir and lake elevation	•	•	•
		Streamflow	✚	✚	✚
	Water Quality	Biogeochemical flux	✧	✧	✧
		Water chemistry	✚	✚	✚
		Ground water quality	✧	•	•
		E. coli	•	✧	✧
		Algae	✧	✧	✧
		Aquatic invertebrate assemblages	✚	✚	✚
		Water temperature	✧	•	•
Biological Integrity	Invasive Species	**Invasive plants**	✚	✚	✚
		Exotic aquatic assemblages	✚	✚	✚
	Infestations and Disease	Forest insects and disease	✧	•	•
		Whitebark pine	–	✚	✚
		Vertebrate disease	✧	•	•
	Focal Species or Communities	Aspen	–	✧	•
		Riparian/riverine	✧	✧	•
		Shrub-steppe	✧	✧	✧
		Insects	✧	✧	✧
		Beaver	✧	✧	•
		Meso-carnivores	•	•	•
		Amphibians	✚	✚	✚
		Landbirds	✚	✚	✚
		Native aquatic assemblages	•	•	•
		Alpine	–	✧	✧
		Cushion plants	✧	✧	–
		Ungulates	•	•	•
	At-risk Biota	Birds of concern	•	•	•
		Large carnivores	✧	•	•

Level 1	Level 2	Vital Sign	BICA	GRTE	YELL
Human use	Visitor and Recreation Use	Backcountry day use	–	•	✧
		Backcountry overnight use	–	•	•
		Visitor use	•	•	•
Ecosystem Pattern and Processes	Fire	Fire	•	•	•
	Land Use and Cover	**Land use**	✚	✚	✚
		Land cover	•	•	•
	Soundscape	Soundscapes	✧	•	•

✚ This symbol shows vital signs that the GRYN is working to develop monitoring plans and protocols (also noted with green shading)
• This symbol shows vital signs that are monitored, to some degree, by a network park or another federal or state agency
✧ This symbol shows vital signs with no known current or planned monitoring
– This symbol indicates that the vital sign does not apply to the park

to consider those vital signs that ranked 0.9 (out of 1.0) or higher as a possible list of vital signs to monitor. This served as a starting point for discussion and highlighted those indicators that should be added or deleted. The TC members then proceeded to add vital signs that had scored below 0.9, given their belief in the importance of the vital sign to monitoring long-term ecosystem health and/or to management policies. This step allowed for the addition of candidate vital signs that may have ranked lower during the workshop due to lack of information or knowledge on their management relevance. For instance, E. coli was added to the vital sign list because the Shoshone River (in Bighorn Canyon) is listed as 303(d), impaired for contact recreation, by the Wyoming Department of Environmental Quality (WYDEQ 2004) because levels of fecal coliform exceed state standards.

The next step in selecting vital signs was to combine or rename those vital signs that had similar meanings, as many proposed candidate vital signs nominated by the Delphi process and the conceptual models had similar meanings but were written in slightly different vernacular, depending upon the background and expertise of the nominator. An important outcome of this exercise was the nomination of invasive plants as a vital sign. Prior to this, invasive plants were scattered throughout different habitat-specific vital signs (e.g. mixed conifer plant community composition and exotic species). Following this process, the TC members addressed each vital sign individually, considering the importance of the vital sign to monitoring ecosystem health and/or its management relevance.

Those vital signs that met with strong approval were added to the prioritized list; similarly, those that had strong disapproval were dropped. For vital signs in which a consensus could not be reached, the TC members selected those vital signs that had ongoing monitoring programs, with the thought that the information derived from these programs would add value to the overall program. Thus, the GRYN selected several dozen vital signs important for monitoring ecosystem health.

The TC then selected a subset of vital signs that would be monitored primarily using I&M funds. This was accomplished by giving each TC participant an opportunity to nominate what they believed was an important vital sign for the I&M program to monitor. This selection of vital signs was based on one or more of the following factors: 1) the information gained from the monitoring program would aid in making management decisions; 2) no standardized monitoring was taking place, thus leaving gaps in monitoring information, 3) the information gained from the monitoring program would help explain changes in ecosystem structure and function; and 4) opportunities exist to augment network funds through partnerships and agreements. Please consult Figure 3.1 for a diagram of the vital sign selection process.

Of the twelve vital signs selected for initial planning and implementation, some are currently being funded from other sources but will benefit from new funds provided through the I&M program. Two of these--streamflow and climate—are currently monitored by other agencies and are, therefore, of minimal additional cost to the I&M program, although these long-term programs could benefit from I&M support. Similarly, several of the metrics of the land use vital sign are gathered by county governments and the cost of compiling this data is relatively minimal. Aridland seeps and springs, in addition to soil function and stability, are specific to Bighorn Canyon, where there is currently little repeat, standardized monitoring taking place. These vital signs therefore represent new additions to monitoring in the ecosystem. The amphibian, landbird and whitebark pine vital signs provide important information on species and communities of concern and facilitate partnerships with the USGS Amphibian Research and Monitoring Initiative (ARMI) program, the Interagency Grizzly Bear Study Team (IGBST) and the Greater Yellowstone Coordinating Committee (GYCC), each of which may help augment monitoring costs for these vital signs. Monitoring of invasive plants, including early detection monitoring, will help warn park managers interested in treating populations before they become a significant resource threat. Additionally, the initial subset of vital signs include a suite of water quality indicators (water chemistry, aquatic invertebrate assemblages and exotic aquatic assemblages) that build a water quality program at Bighorn Canyon and integrate with ongoing monitoring at Yellowstone and Grand Teton.

A complete list of vital signs can be found in Table 3.2. Nearly all selected vital signs can be directly tied to one or more conceptual models; the majority of these also were directly nominated as vital signs through the modeling exercises. Figure 2.1 and Table 2.2 in Chapter 2 illustrate an aquatic ecosystem conceptual model with several candidate vital signs that were subsequently cross-walked with the Delphi-nominated candidate vital signs, ranked at the vital signs workshop and later selected by the Technical Committee.

None of the vital signs under the "air and climate" section of the framework were directly nominated by the modeling process because there were no models that directly addressed atmospheric concerns. This weakened the ability of the models to identify indicators from this area. Thus, although there were a number of vital signs whose origins cannot be directly tied to the conceptual models, it was generally due to an oversight in the creation of the model categories, rather than on the modeling process itself. Conversely, many of the potential vital signs in other framework categories were nominated through both the Delphi survey and conceptual modeling processes.

APPROVAL AND PEER REVIEW

Following selection of the vital signs, the Board of Directors approved the Technical Committee members' recommendations with the understanding that available funding through the Natural Resource Challenge was likely insufficient to monitor all 12 vital signs and, therefore, some deletions or reductions in monitoring objectives are to be expected. During the protocol development phase, costs can be more accurately estimated and tradeoffs can be assessed because the monitoring objectives are more specific and the sampling design has been considered.

Peer review of the Phase III Vital Signs Monitoring Plan took place in early 2005. Peer reviewers included members of the NPS National Water and Air Resource Divisions, Regional and Washington office I&M staff and an academic reviewer. Following the peer review, the GRYN Technical Committee provided input and direction on vital sign budget priorities.

RELATIONSHIP BETWEEN THE NETWORK AND PARK-BASED MONITORING ACTIVITIES

It is impossible for any monitoring program on a limited budget to develop a complete picture of ecosystem health with its staff and funding alone; thus, many of the network's subset of 12 vital signs were chosen to "fill the gaps" in current monitoring in the parks and allow time and money to be spent on issues that had high management relevance and would create a more complete picture of ecosystem health when synthesized with ongoing monitoring of other vital signs.

It is essential that the network integrate with ongoing park monitoring programs to maximize the amount of information available to make informed management decisions. To successfully synthesize and report on the state of the parks' ecosystems, the network will work with the parks to update and revise existing protocols, as well as provide direct assistance with data management. The network will collaborate with park staff to develop mutually accepted minimum requirements for existing and future protocols for monitoring in the parks. This process will allow for shared involvement in the construction of protocols for monitoring that is funded mainly by the parks, instead of the I&M program, and will lead to consistency among projects. While the amount of change to the protocols necessitated by these guidelines will vary, the network will attempt to provide technical resources when possible to facilitate this process.

In addition to updating and revising protocols, the network will work with park staff to create models for database and information management, with the goal of increasing the usefulness of collected data. This process will involve building aquatic and terrestrial database models through a user requirements and systems analysis for aquatic and terrestrial information management. The purpose of this exercise is to outline the information needs of both the park and monitoring program before designing the database model. The network will also relay information to numerous end-users by using a Web-based interface.